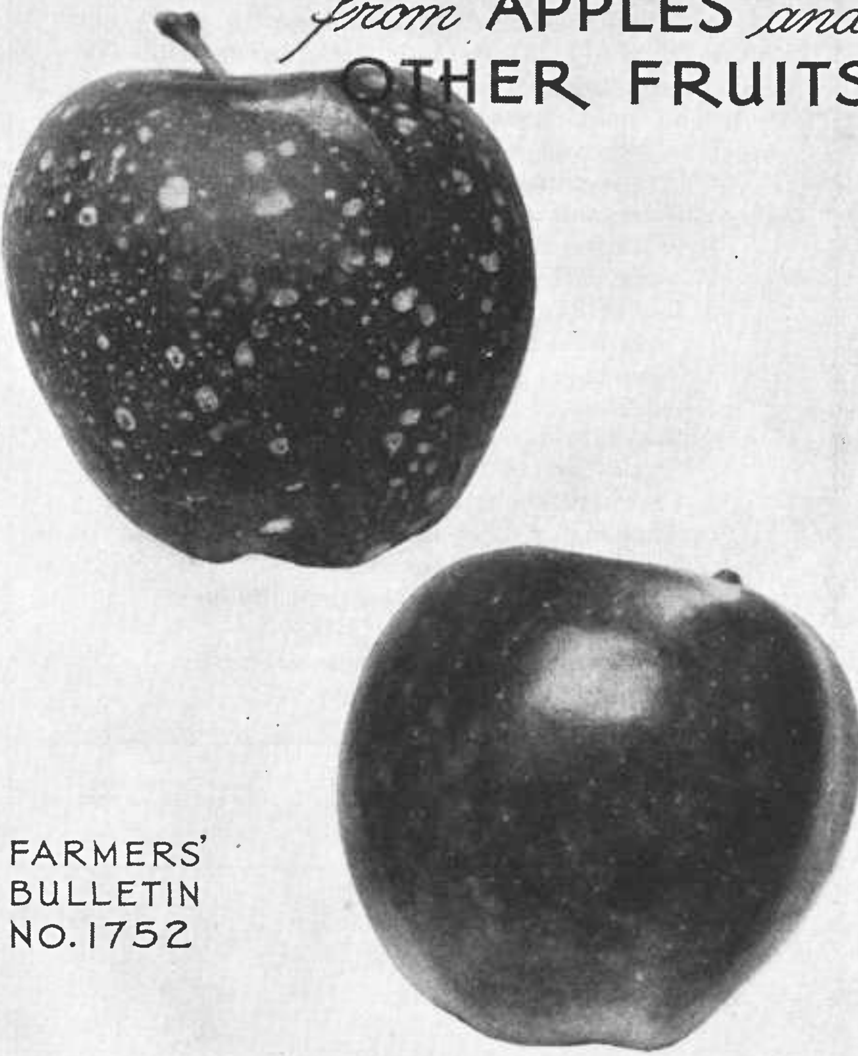
Spray-RESIDUE REMOVAL from APPLES and OTHER FRUITS



FARMERS' BULLETIN No. 1752

U.S. DEPARTMENT of AGRICULTURE

SPRAYING—which is necessary for the adequate production of crops of sound apples, pears, and other fruits to fulfill the nutritional needs of the Nation—frequently leaves on the fruit at harvest excesses of lead, arsenic, or fluorine. Such residues must be removed before the fruit is marketed.

Effective residue removal with minimum injury to the fruit depends on—

1. Selection of suitable washing equipment for the variety of fruit and the spray treatment.
2. Use of the right washing solution (hydrochloric acid or sodium silicate) for the washer selected.
3. Addition of suitable fortifying materials.
4. Regulation of the concentration and the temperature of the washing solution.
5. Frequent changing of the washing solution.
6. Thorough rinsing of the fruit at the end of the proper washing period.

Difficulty of residue removal depends on—

1. Growth conditions.
2. Kind, variety, and ripeness of fruit.
3. Amount and kinds of sprays.

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SPRAY-RESIDUE REMOVAL FROM APPLES AND OTHER FRUITS

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Contents

PROBLEM OF REMOVING SPRAY RESIDUES

SPRAYING with lead arsenate has been for many years the most effective and economical means of controlling the codling moth on apples and pears, also other insects on various fruits. Other arsenical sprays and those containing fluorine have also been used. Apples, pears, and other fruits sprayed with these materials frequently bear at harvest excessive residues that must be removed prior to sale.

The Federal Security Agency has established regulatory tolerances for arsenic, fluorine, and lead. These tolerances for 1943 are 0.025 grain of arsenic as arsenic trioxide, 0.020 grain of fluorine, and 0.050 grain of lead per pound of fruit.

Considerable effort has been made by the United States Bureau of Entomology and Plant Quarantine and other agencies to discover and develop substitutes for lead arsenate. So far no substitute that is generally effective in controlling the codling moth and economically feasible has been found. Until such a substitute is found the fruit grower must continue to rely on the present spray materials and must remove the excess residue.

Because of the increasing difficulty of controlling the codling moth, heavier and more frequent applications of spray have been made, and oils and other stickers have been added to the sprays. These changes have increased the difficulty of spray-residue removal and have emphasized the need for effective removal methods.

Lead arsenate is also used to control the cherry fruitfly, grapeberry moth, plum curculio, and currant worm. Although the sprays to control these insects are generally applied early in the season, ex-

cess residues have been found on fruit at harvest, and methods of removing these excesses may be needed.

Experience has shown that dry wiping or brushing cannot be depended on to remove appreciable quantities of spray residue from most fruits. This bulletin, therefore, will deal almost entirely with residue removal by washing. Special emphasis has been put on apples, which usually need washing more than other fruits and therefore have been studied most.

WASHING EQUIPMENT, SOLUTIONS, AND PROCEDURES

FRUIT-WASHING EQUIPMENT

The choice of washing equipment will depend on the quantity of fruit to be washed, the kind of washing solution used, and the difficulty of cleaning the fruit.

Dipping Tanks

For the small grower who has only a few hundred bushels of fruit to clean, an expensive commercial machine is, of course, out of the question. Under such circumstances dipping tanks that will effectively remove the residues likely to be encountered may be constructed at relatively small cost. Such equipment should consist of two similar tanks, one for the washing solution and the other for the rinsing bath. The tanks should be large enough to accommodate one or more crates, depending on the capacity desired, and should be connected by a drainboard to permit the excess washing solution to drain back into the wash tank before the fruit is dipped into the rinse tank. Slatted crates or boxes with weighted removable covers are convenient containers to use in the tanks. Hydrochloric acid should be used as the washing solution in dipping tanks. The concentration and time of exposure necessary will depend on the difficulty with which the spray residue is removed. Usually it is sufficient to use 1-percent hydrochloric acid and to expose the fruit to the acid solution for 2 to 3 minutes. With varieties of apples that have open calyx tubes, such as Stayman Winesap, there is danger of the wash solution penetrating to the core and causing decay. Washing in dipping tanks is laborious and inconvenient and is recommended only when the quantity of fruit to be cleaned is too small to justify the use of more expensive equipment.

Flotation Machines

In the flotation type of washer the fruit floats through the tanks on the surface of the solution and is turned and submerged occasionally by means of slowly revolving paddles or by cloth drapes or brushes hanging down in the solution. The fruit may be pushed through such machines by feeding in additional fruit, by the paddles, by slat conveyors, or by other means. Machines of this type are simple and relatively inexpensive. They are economically feasible for the small grower with only a few thousand bushels of fruit to clean but can also be obtained in large sizes with capacity for washing 2,000 to 3,000 bushels per day and can be used in large orchards or in packing houses. They can be recommended where the difficulty of residue removal is not too great and where acid solutions are particularly applicable, as under eastern conditions (p. 13). They are relatively

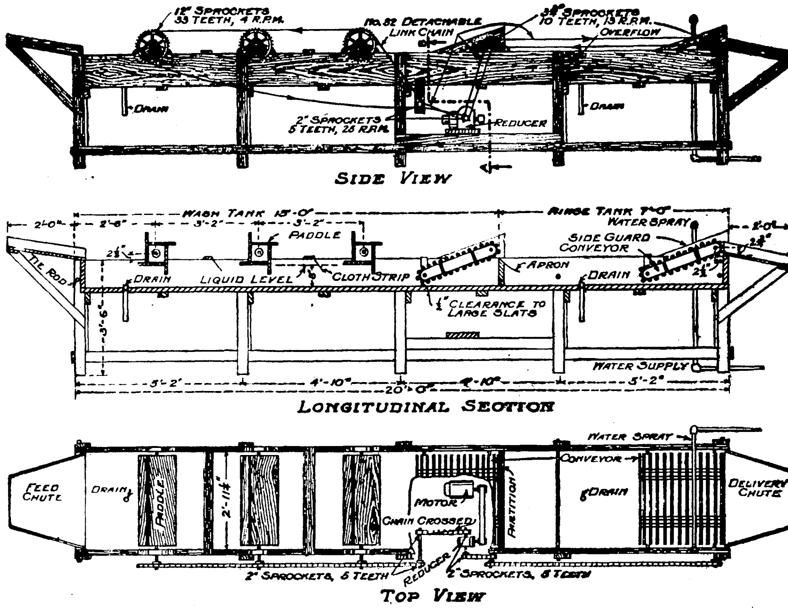


FIGURE 1.—Drawings of a modified paddle washer.

ineffective with fluorine-spray residues. Most flotation washers are not suitable for pears, as most varieties will not float in water (p. 19).

The flotation type of cleaning equipment can be obtained from commercial manufacturers or can be home-made, as shown in figure 1. Detailed plans for the construction of such a washer may be obtained by writing the Plant Industry Station, Beltsville, Md.

Flood Machines

In most machines manufactured commercially the washing solution and rinse water are flooded over the fruit as it is conveyed through the machine by "walk-along" or "shuffleboard" conveyors or by rapidly rotating brushes. The fruit is usually flooded either by impeller paddles that throw the solution over the fruit or by pumping the solution into a sluiceway above the fruit and allowing it to flow down through baffles. A shorter period of exposure of the fruit to the washing solution is required in flood than in flotation machines because of the more rapid renewal of the solution on the fruit in the flood machines. Sodium silicate can be used in flood machines but is relatively ineffective in flotation machines. Except for these advantages, flood machines without brushes are not appreciably more effective in removing spray residue than flotation machines when acid solutions are used.

Transverse, rotary under brushes with the jute bristles or rubber fingers, when used in place of the walk-along conveyor in flood washers, have been found by experiment to increase residue removal appreciably. The mechanical action of brushes has been found to be especially effective in removing residues from fluorine sprays. Efficiency has been increased in all types of wash solutions, but the most outstanding results have been obtained with those containing sodium

silicate or hydrochloric acid and mineral oil. Certain mechanical difficulties have prevented the general adoption of brushes by washing-machine manufacturers, but the increase in cleaning efficiency through the use of brushes warrants their more general adoption.

Dual-Process Machines

The so-called double-process machine is essentially a combination of two flood machines. Such a combination permits the use of two different washing solutions each followed by a rinse. Usually a sodium silicate solution is used in one wash tank and a hydrochloric acid solution in the other. Such machines may be necessary for fruit that is very difficult to clean. Their effectiveness might be increased if they were manufactured with rotating brushes instead of with other types of conveyors.

WASHING SOLUTIONS

As already mentioned, the two materials that have proved most satisfactory for the removal of spray residues are hydrochloric acid and sodium silicate.

Hydrochloric Acid

Washing solutions of hydrochloric (muriatic) acid are particularly applicable for fruit sprayed with lead arsenate and lime or with fungicides containing lime and for that sprayed with calcium arsenate, manganese arsenate, or fluorine compounds. Hydrochloric acid may also be used with apples that have not developed excessive wax and have been sprayed with lead arsenate alone (without lime) or with lead arsenate and a spreader, fish oil or soap.

For fruit washing the commercial grade of hydrochloric acid is used. This acid is very corrosive, particularly in the concentrated form, and will burn the flesh and clothing unless immediately washed off with fresh water or an alkaline solution such as bicarbonate of soda or lime. It should, therefore, be handled with great care, and it is advisable to keep on hand a supply of hydrated lime or baking soda in case of accident.

The acid is usually obtained in 12-gallon carboys, and a carboy-tilting frame or inclinator will be found convenient in removing the acid from the carboy to smaller containers, which should be of glass, porcelain, or earthenware. The dilute solutions are less corrosive but will react readily with lime and cement and slowly with metal such as iron, copper, and tin. Where possible, therefore, metal parts of machines should be protected with heavy oil or paint, and concrete floors should also be so protected.

The used acid solution should not be emptied into irrigation ditches or around trees and other useful plants. Where the waste acid is diverted to sewerage systems it is well to dilute it with copious quantities of water as it flows into the sewer and to flush the latter with water after the used solution has passed out.

The commercial grade of hydrochloric acid should test 20° Baumé, which indicates a solution of about 32 percent of actual acid in water. One gallon of 20° acid (specific gravity 1.16) contains about 3.1 pounds of hydrochloric acid. This, added to 100 gallons of water (weighing

833 pounds), makes a solution containing about 0.36 percent of acid by weight. A 1-percent solution, therefore, requires about 2.8 gallons of the undiluted acid to 100 gallons of water.

The strength of the acid solution can be readily determined by a simple titration method. For this, the following equipment and material are needed:

One 10-milliliter bulb pipette.

One 10-milliliter Mohr pipette graduated in 0.1-milliliter intervals, or one burette and stand.

One porcelain cup glass tumbler, or small wide-mouthed bottle.

A standard solution containing exactly 23 grams of pure bicarbonate of soda per liter of water and enough methyl orange indicator to give the solution a distinct yellow color.

The pipettes can be obtained from any chemical supply house, and the standard soda solution can usually be made up by local druggists. The procedure is as follows: Using the bulb pipette, transfer 10 milliliters of the washing solution to the cup or tumbler. To accomplish this draw the acid solution by suction into the pipette until it is filled above the 10-milliliter mark. Hold the pipette between the thumb and fingers, leaving the forefinger free to place over the upper opening of the pipette as soon as it is withdrawn from the mouth. Permit the solution to drain slowly from the pipette (by rotating the pipette between the thumb and fingers while holding the forefinger lightly pressed against the upper opening) until the surface of the liquid reaches the mark on the upper stem. The pipette now contains 10 milliliters of acid solution, which should be transferred to the glass tumbler or cup.

In a similar manner fill the graduated pipette with the standard bicarbonate solution, adjusting the level of the liquid to the 0 mark. Allow the bicarbonate solution to drain slowly into the 10-milliliter sample of wash solution in the tumbler, constantly shaking or stirring the latter solution. The methyl orange will color the acid solution red until all of the acid has been neutralized by the bicarbonate solution, when the color will change to yellow. When this color change occurs, stop adding the bicarbonate solution and note the quantity of bicarbonate used. The number of milliliters used divided by 10 gives the percentage concentration of hydrochloric acid in the solution tested. For example, 3.6 milliliters of bicarbonate solution would indicate an acid concentration of 0.36 percent, which is equivalent to about 1 gallon of undiluted acid to 100 gallons of water.

The concentration of the acid wash solution can be increased to any desired point by adding undiluted acid to it at the rate of 1 quart per 100 gallons for each increase of 0.09 percent of acid desired. Thus, if the concentration in the tank is found to be 0.73 percent and the concentration desired is 1 percent, it will be necessary to increase the concentration by 0.27 percent; the addition of 3 quarts of undiluted acid for each 100 gallons of solution will be required.

During the washing process the hydrochloric acid reacts with the lime and other residues on the fruit, thus reducing the concentration of the acid. Some of the solution is carried out of the tank on the fruit and on certain types of conveyors. Water and acid must therefore be added at intervals to maintain the solution at the proper level and concentration. This can be done best by first adding the necessary water. After thorough mixing of the solution, test the concentration and add the required amount of acid.

The removal of spray residues by washing with hydrochloric acid solutions is primarily a chemical reaction, and the completeness or effectiveness of the reaction will depend on the time of exposure of the fruit to the acid, the concentration and temperature of the solution, and the presence of fortifying agents that may assist either chemically or physically the action of the acid.

The time of exposure of the fruit to the acid is usually 30 to 60 seconds in flood machines and 60 to 120 seconds in flotation machines. The longer exposures remove the residues more effectively, but the briefer exposures are frequently given in order to use the machine to maximum capacity.

The concentration of acid used ranged from 0.5 to 1.5 percent. The lower concentration is about the minimum that can be effectively used and is applicable only to lots of fruit that are relatively easily cleaned. Little additional cleaning is obtained by concentrations greater than 1.5 percent, and the use of concentrations above 1.5 percent makes satisfactory rinsing difficult.

When the maximum practicable time of exposure and concentration of acid are used and are not sufficiently effective in removing the residues, the addition of fortifying agents or heating the washing solution or both must be resorted to.

The addition of 0.5 to 1.0 percent (4 to 8 pounds per 100 gallons) of certain acid-resistant wetting or degumming agents has been found in most cases to increase greatly the effectiveness of both cold and warm acid washing solutions. There are on the market various materials that act as wetting agents. Some of these are proprietary preparations. These preparations are not usually pure compounds but mixtures of materials the proportions of which may vary somewhat from time to time; this variation may influence their effectiveness as aids in washing. Some of these are of no benefit in removing spray residues, and others injure the fruit.

Wetting agents act in a manner similar to soap in that they increase the wetting of the surface and may have a detergent action, thus physically removing some of the oil, wax, dirt, and spray material from the surface of the fruit. For this reason wetting agents are particularly applicable to oil-sprayed or waxy fruit. Wetting agents are adapted to flotation machines. When wetting agents are used with acid solutions, heat or lenticel injury is more apt to occur than when acid alone is used; consequently, the temperature of heated solutions should be maintained at a slightly lower point with wetting agent and acid combinations. Likewise, rinsing needs to be more effective when wetting agents are used.

Wetting agents should not be used commercially until they have been tested and found to increase the efficiency of the washing solution without injuring the fruit. For specific information about wetting agents inquiries should be addressed to the United States Department of Agriculture or to State experiment stations.

The addition of an odorless kerosene or very light mineral oil of highly refined, white spray-oil type (viscosity 50 to 60 seconds Saybolt) at the rate of 1 gallon to 100 gallons to heated acid solutions has been found very effective with oil-sprayed or waxy fruit. Nonemulsified oil or kerosene, preferably the former, should be used. It is important that the oil be very light and have a viscosity as specified above, as a heavier oil may be detrimental rather than bene-

ficial. It should also be emphasized that this washing treatment is effective only with solutions that are heated to 90° F. or above and only in washers such as the flood or flood-brush machines, in which there is a distinct agitation of the washing solution. A light mineral oil added to an acid solution reduces the danger from heat injury and allows higher temperatures to be used. Small amounts of the oil adhere to the surface of the fruit and are carried off. Quantitative tests for the amount of mineral oil present in the hydrochloric acid solution containing mineral oil after various periods of operation have shown that the decrease in oil concentration due to the carry-over on the fruit is, roughly, one-half gallon per 100 gallons of solution every 3 hours at 110°. Thus, in order to maintain a fairly constant mineral oil concentration, one-half gallon per 100 gallons of solution should be added three times a day or at the following times: Middle of the morning, noon, and middle of the afternoon. At lower solution temperatures the carry-over of oil will be slightly greater because of its greater viscosity; at temperatures higher than 110° the carry-over will be slightly less. The addition of greater amounts of oil to the solution ordinarily does not increase the cleaning efficiency, though under certain conditions of cleaning it has been found necessary to add oil until the slightly oily appearance of the fruit indicates that it has been effective in softening the residue and wax. Oil or kerosene used in the washing solution removes some of the oil or wax from the surface of the fruit. This may result in increased loss of moisture from the fruit and consequent shriveling unless the fruit is held at relatively high humidities after such treatment.

Raising the temperature of the washing solution from room temperature to 90° to 110° F. tends to soften the oily or waxy deposit on the surface of the fruit and may increase the speed of the chemical reaction and the solubility of the residues, thus increasing considerably the effectiveness of removal. The temperature that can safely be used will depend on the variety and condition of the fruit, the time of exposure to the solution, and the kind of solution used, as indicated on page 18.

Sodium Silicate

Heated solutions of sodium silicate have been found very effective for removing the residue from apples that have been sprayed with lead arsenate and fish oil or with lead arsenate and mineral oil and from those that have become waxy. Sodium silicate solutions are less effective than acid solutions for apples that have been sprayed with cryolite, calcium arsenate, manganese arsenate, or lead arsenate and lime or fungicides containing lime. For this reason sodium silicate is not generally applicable to eastern conditions (p. 13).

Sodium silicate can be obtained in a number of different forms. The form which has been commonly used for fruit washing and which has proved satisfactory for this purpose has a ratio of 1 part of sodium oxide (Na_2O) to 1.58 parts of silicon oxide (SiO_2) and has a sodium (Na) content of approximately 15 percent. Sodium silicate is obtained as a thick, very viscous clear liquid or as crystalline cakes. When obtained in the latter form, the material is dissolved by being put in a small quantity of water and steam injected. This solution is then added to the water in the wash tank. Because of its very high viscosity sodium silicate does not mix readily with water. For this reason care must be taken in adding it to the washing solution. Ordi-

narily this is done either by previously mixing it thoroughly with a small portion of water or by pouring it slowly into the heated solution as it flows from the pump flume. After the sodium silicate has been added, a thorough mixing should be accomplished by running the machine for 15 minutes before any fruit is washed.

Sodium silicate is alkaline in reaction and considerably less corrosive, particularly to metals, than is hydrochloric acid. However, it should be handled with care and the waste solution disposed of as directed for acid solutions (p. 4).

The concentration of the sodium silicate solution can be determined by titration in a manner similar to that used for testing an acid solution. The materials necessary are the same except that a standard acid solution is used instead of a standard soda solution. A 0.756 normal (2.75 percent) solution of hydrochloric acid to which has been added sufficient methyl orange indicator to give a distinct red color should be used. A 10-milliliter sample of the sodium silicate solution to be tested is titrated with the standard acid solution until the red color is no longer changed to yellow. The number of milliliters of acid used multiplied by 10 gives the concentration of sodium silicate in pounds per 100 gallons. Thus, if 7.0 milliliters of acid are used, the concentration of sodium silicate is 70 pounds per 100 gallons. If a concentration of 80 pounds per 100 gallons is desired, 10 pounds of sodium silicate per 100 gallons should be added to the above solution. This determination applies only when the sodium silicate has a sodium content of approximately 15 percent.

Sodium silicate solutions combine solvent and detergent actions and tend to remove dirt, oil, and wax from the fruit as well as to dissolve and wash the spray residue from the fruit. To be effective, sodium silicate solutions must be heated to 90° F. or above and must be used in machines in which there is a distinct agitation of the wash solution, as in flood washers.

Sodium silicate is commonly used at concentrations of 40 to 80 pounds of sodium silicate to 100 gallons of water and at temperatures of 90° to 120° F. The use of the higher concentrations may give somewhat more effective removal than the lower ones. More benefit, however, may be expected from the use of relatively high temperatures. Temperatures of 110° to 120° and exposures of 20 to 35 seconds are frequently used, particularly with apples that have been in storage. The temperatures that may be safely used are discussed on page 18.

As with the acid solution, certain fortifying agents may be used with sodium silicate solutions to increase their effectiveness in removing residues. For this purpose soap may be added in quantities sufficient to given as much foam as the machine will handle. In addition to soap, kerosene, or preferably a very light mineral oil (viscosity 50 to 60 seconds Saybolt) at the rate of 1 gallon to 100 gallons has been found of benefit. Rotating brushes under the fruit are of considerable benefit with sodium silicate solutions.

Ripening of the apples during storage facilitates the removal of spray residues when sodium silicate washing solutions are used. Lots of apples that are difficult to clean at harvest may be readily cleaned with sodium silicate after a period of ripening in storage. Apples that have been in cold storage for 3 to 5 weeks may be washed without injury to their keeping quality.

WASHING SOLUTIONS FOR DIFFERENT TYPES OF WASHERS

With flotation machines hydrochloric acid solutions only should be used. In such machines a wetting agent may be added for increased effectiveness. These solutions may be used at room temperature or heated. The most effective cleaning in such a machine should be obtained by using the maximum practicable and safe concentration of acid, temperature of solution, and time of exposure and by adding a wetting agent.

With flood machines either hydrochloric acid or sodium silicate solutions may be used. The hydrochloric acid solutions may be fortified with light mineral oil, and the sodium silicate solutions may be fortified with soap or with soap and light mineral oil. The acid solutions can be used either at room temperature or heated. The acid solutions with oil and the sodium silicate solutions must be warmed to be effective.

With flood machines with brushes the same solutions may be used as in flood machines without brushes; however, the brushes will be most effective with the sodium silicate solutions or with the acid-oil combination.

In dual-process machines the same solutions may be used as in flood machines. Although hydrochloric acid or sodium silicate solutions can be used in both wash tanks of such machines, the most effective removal is generally obtained by using a sodium silicate solution in the first tank and an acid solution in the second for oily or waxy fruit that has not been sprayed with lime or alkaline materials. With fruit that has been sprayed with a mixture containing lime equally effective removal may be obtained with acid in both compartments, with acid followed by sodium silicate, or with sodium silicate followed by acid. If sodium silicate is used in the second compartment a more effective final rinse is necessary than when acid is used.

METHODS OF HEATING THE SOLUTIONS

As has been stated previously, some of the washing solutions must be warmed to be effective, and the effectiveness of others may be increased by warming. The washing solution may be heated by means of electric immersion heaters, by releasing live steam into the solution, by placing hot-water or steam coils in the solution, or by circulating the washing solution through water heaters.

A convenient method of heating the solution is by means of acid-resistant bayonet-type electric heaters that are inserted in the washing solution. One heater of about 8-kilowatt capacity will be needed for each 100 gallons of washing solution. Electric heaters can be thermostatically regulated so as to maintain a constant temperature without hand regulation. The installation of electric heaters usually requires a larger transformer to meet the power requirement and necessitates some extra wiring, all of which increases the expense of heating by this method. The operation of the heaters consumes considerable power so that if the power rate is high the convenience of heating by this method is more than offset by the additional cost as compared with that of heating by other methods.

Releasing live steam directly into the washing solution has been found a convenient and practical method of warming the solution. A steam boiler that can be used for this purpose is frequently avail-

able so that no immediate expenditure for equipment is necessary except for sufficient piping or hose to carry the steam from the boiler to the wash tank. By releasing the steam at several points in the tank more even heating can be obtained. Because condensation of the steam tends to dilute and weaken the washing solution, the concentration of the solution must be tested at frequent intervals and the necessary materials (hydrochloric acid or sodium silicate and fortifying agents) added to maintain the desired concentration.

Where a small boiler or water heater is available, or where low-pressure steam is required for other purposes, the solution can be warmed by means of a coil in the wash tank through which the steam or hot water is circulated. If hot water is used, a small pump is needed to circulate it through the coils. It is not necessary to build up a system of coils in the wash tank; a pipe may simply be given a turn about the tank and brought out at the opposite end. Inlet and outlet valves are provided for controlling the flow of steam or hot water through the tank in order to regulate the temperature of the cleaning solution. This method of heating should be more applicable to sodium silicate solutions, as acid solutions would attack the coil and make necessary its replacement from time to time. Monel or other acid-resistant metal may be used for steam coils in acid solutions. If welded joints are used, rather than threaded connections, coils of this type will give several seasons' service in heated acid solutions.

In dual-process machines it is a common practice to heat the acid solution by the injection of live steam and the alkaline solution by the installation of steam coils.

In a flotation washer the solution cools at a slower rate than in machines in which it is agitated and aerated by paddles or pumps. Where rapid heating and a close control of temperatures are necessary, a steam boiler is a necessity, and thermostatic control is most important to insure uniformity in residue removal and the avoidance of injury from excessive temperatures.

Thermostatic Control of Heating

With the increased use of heated solutions a thermostat that automatically controls the steam valve has become an essential part of the heating equipment. Some ideal heating plants have been made by fitting an automatic oil burner on an old threshing-engine boiler and placing a thermostat on the steam line between the boiler and the washing machine. The temperature of the washing solution controls the steam valve, and the steam pressure in the boiler controls the automatic oil burner, so that as long as fuel oil and water are furnished to the boiler the temperature of the washing solution remains constant for an indefinite length of time.

Boilers may be obtained with this equipment installed as well as with automatic water injectors.

RENEWING THE SOLUTION

During the washing process dirt and spores of decay-producing organisms are continually washed from the fruit. The removal of the spores by fresh wash solution and rinse water would tend to improve the keeping quality of the fruit. The spores, however, ac-

cumulate in the wash solution until they become a hazard to the fruit being washed. Likewise arsenic and fluorine are removed from the fruit in a soluble form and accumulate in the wash tank. The soluble arsenic and fluorine will burn the skin of the apples unless completely removed by the rinse water. A heavy accumulation of arsenic or fluorine in the wash tank may overtax the rinsing facilities. Because of this accumulation of soluble residues, spores, and dirt, it is necessary that the used solutions be drained from the wash tank and fresh solution be added after the tank has been thoroughly cleaned. This should be done after each day's run, or after 1,000 to 1,500 bushels of fruit have been washed per 100 gallons of solution.

RINSING THE FRUIT

Properly rinsing the fruit is a very important part of the washing process and can do much toward eliminating the danger of injury from the washing solutions or soluble residues and decay-producing spores in the washing solution. For effective rinsing, from 3 to 4 gallons of fresh water per bushel of fruit washed should be added to the rinse tank as a spray on the fruit as it leaves the tank. Instead of having this introduced from a single transverse pipe across the rinse section some operators have added a second transverse spray pipe so that the fresh water hits the fruit from two angles and in twice the volume. Machines thus equipped have washed fruit with a minimum of injury from the washing treatment.

When sodium silicate is used as the washing solution or when wetting agents or mineral oils are added to hydrochloric acid solutions, more thorough rising is required than when hydrochloric acid only is used in the washing solution. Fruit washers are generally constructed with the rinse section only about half as large as the wash section. This size is usually sufficient when hydrochloric acid alone is used as the washing agent, but a larger rinse section is desirable when sodium silicate is used or wetting agents or mineral oils are added to the hydrochloric acid.

When an acid solution is used and the supply of fresh water is limited, the same rinse water can be used continuously by adding sufficient lime to keep the rinse water neutral or slightly alkaline. The lime neutralizes the hydrochloric acid carried over on the fruit and renders insoluble the arsenic remaining on the fruit after washing. Usually 2 pounds of slaked lime or broken limestone to 50 gallons of rinse water is sufficient. As the lime becomes exhausted by the acid, additional lime must be added at intervals. The rinse water can be tested with red litmus paper, which should turn blue. If it remains red the rinse water is acid, and more lime must be added. A simple method of testing the effectiveness of rinsing when an acid wash solution is used is to taste the water in the calyx basin of the apples as they leave the rinse section. A slightly sour taste indicates that the acid has not been completely neutralized or rinsed off.

It is important that apples turn over in the rinse section so that the calyx basin is thoroughly rinsed.

For more effective rinsing it would seem desirable that washing machines be constructed with two rinse sections, particularly where the supply of rinse water is inadequate. It would then be possible to

add lime to the first rinse section and to use this water continuously and to use the available fresh water in the second rinse section. When lime is used in the rinse tank the water should be drained and renewed as frequently as possible.

DRYING THE FRUIT

If the fruit is sound and the washing and rinsing operations are carefully done, drying the fruit is not essential to protect its keeping quality, although it may be desirable in order to facilitate packing. In most commercial machines the drying is accomplished by means of absorbent cloths that are drawn over the rotating fruit and absorb the excess moisture. The water is then removed from the cloths by a wringer. This treatment also removes insect specking, dirt, and other residues not removed by washing. Such driers can be obtained as separate units for home-made washers if drying is considered sufficiently important to justify the expense. Driers in which heated air is blown over the fruit are also in use and are effective in removing the excess moisture.

DETERMINING THE EFFECTIVENESS OF WASHING

Because of the many factors that influence the ease of spray-residue removal, such as the spray treatment, climatic conditions, and variety and maturity of fruit, it is impossible to state what washing treatment will satisfactorily clean a given lot of fruit. Experience may indicate approximately the washing treatment that should be used, but the fruit must be analyzed after washing to determine whether the washing treatment has been effective. Since the amount of residue retained during the growing season varies with different varieties and the ease of removal by washing varies with the variety and maturity, it is necessary that each variety be analyzed separately, as a washing treatment that is effective for one variety may not be for another even though both received the same spray treatment. Likewise, it is necessary that the fruit be analyzed at intervals as the ease of removal may change with maturity or ripeness and a washing treatment that is effective with early-picked fruit may not be with late-picked fruit. In choosing a sample for analysis, fruit of the smallest size and that which appears to have the most residue should be taken, as these are the types of fruit that are likely to be selected by those responsible for the enforcement of spray-residue tolerances. It is important that the analyses be made by a competent chemist. With fruit sprayed with lead arsenate it is more important that the lead residue be determined than the arsenic residue, as any treatment that effectively removes the lead will almost certainly be effective for the arsenic also.

COST OF WASHING

The cost of washing apples varies considerably, depending on the size of the crop, the difficulty of removing the spray residue, the cost of analysis, and other factors. With fruit that is difficult to clean and requires heated solutions, dual-process machines, and frequent analyses, the cost may be as much as 5 cents or more per box. With a large crop of apples that are easily cleaned and require only simple,

inexpensive washing equipment and relatively weak solutions at room temperature, the cost may be less than 1 cent per bushel.

WASHING APPLES

FACTORS AFFECTING SPRAY-RESIDUE REMOVAL

Climatic and Cultural Conditions

The warm, arid conditions prevailing during the growing season in the irrigated valleys of the Pacific Northwest are favorable to the development of the codling moth, and more cover sprays are usually applied there than in the fruit-growing districts of the Central and Eastern States. Therefore, less spray material is usually applied to the trees under eastern conditions, so that at harvest the amount of residue, and consequently the difficulty of removal, is usually less in the East than in the irrigated sections of the West.

Although weather conditions in the irrigated sections are favorable to the development of the codling moth, they are not favorable to the development of apple scab or bitter rot; consequently fungicides and lime to prevent arsenical burning are not commonly used there. The use of lime or of fungicides containing lime as practiced in the East probably increases the amount of weathering and may facilitate removal with acid washing solutions, but makes alkaline washing solutions such as sodium silicate relatively ineffective. In many respects, therefore, the problems of spray-residue removal under eastern conditions are quite different from those in the irrigated valleys of the West and will frequently be discussed separately. In this bulletin the expression "northwestern conditions" refers to conditions that prevail in the irrigated valleys of the West, and "eastern conditions" to those in other parts of the country where considerable rainfall normally occurs during the summer and fall.

Annual differences in climatic conditions prevailing in a given district may also influence the difficulty of residue removal. Weathering-off of the residue does not appear to be influenced by the amount of rainfall. Temperature may be a factor, as abnormally warm conditions just previous to harvest may stimulate an earlier or heavier wax development that may retard residue removal.

Variety, Maturity, and Ripeness

Varieties vary considerably in the amount of spray retained during the growing season and in the difficulty of cleaning after harvest. These differences are probably associated with the differences in size of fruit, the roughness of the skin, and the quantity and quality of wax that develops. Difficulty of cleaning depends on the maturity and ripeness of the fruit and the method of cleaning used. Varieties that develop considerable wax, such as Arkansas (Black Twig), Arkansas Black, and York Imperial, particularly if fairly ripe when washed, are likely to be relatively difficult to clean with acid solutions. On the other hand, such varieties are probably not more difficult to clean with sodium silicate solutions than less waxy varieties, as wax development does not interfere with removal with such solutions.

The development of waxy or oily materials on the surface of the fruit takes place throughout the growing season, but the deposit becomes particularly noticeable during the harvest season and especially after

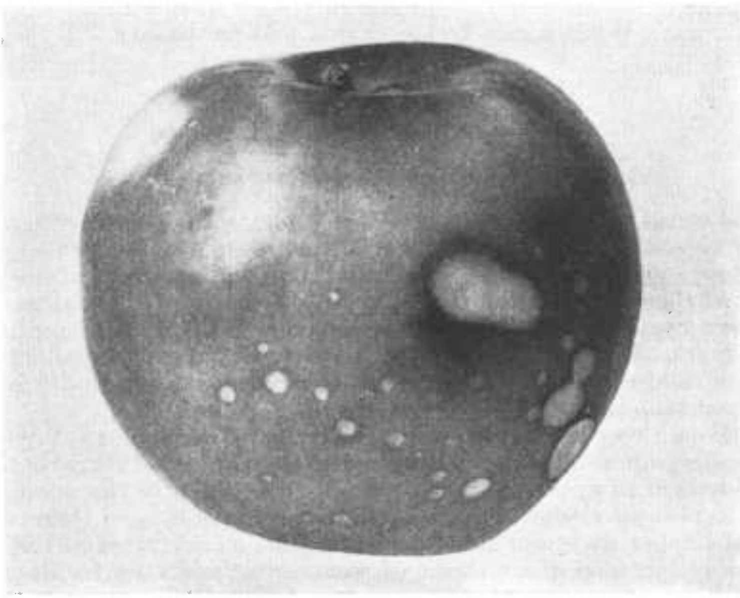


FIGURE 2.—Apple showing typical acid injury.

harvest as the fruit approaches a ripe condition. This waxy deposit interferes with cleaning when acid solutions are used, but it may facilitate removal with sodium silicate solutions. When lime is not used in the cover spray, sodium silicate is indicated for the cleaning solution with ripe fruit of waxy varieties. When acid is used as the washing agent, the fruit should be washed promptly after picking or should be placed in cold storage to retard wax development until it can be washed. When an acid wash solution is used for waxy or oily fruit, the addition of a wetting agent in a flotation washer or a light mineral oil in a flood washer and heating the solution may be necessary. Where both tender varieties and those developing wax have to be cleaned, it may be desirable to use acid cleaning solutions during the first part of the harvest season and sodium silicate solutions with the later or more waxy varieties.

Spray Treatment

The method of washing and the difficulty of residue removal are intimately associated with the spray program followed. In planning a program consideration should be given both to the effective control of the codling moth and to the possibility of effective residue removal. It should be emphasized that omitting late sprays or applying less effective substitute sprays in an attempt to avoid the necessity of fruit washing may result in heavy losses from wormy fruit. On the other hand, the possibility of complications in washing should also be kept in mind and, if possible, sprays that may make cleaning difficult should be avoided.

The adoption of sanitary measures such as scraping and banding the trees, removing rubbish, and sterilizing old boxes or baskets before they are distributed in the orchard reduces the codling moth

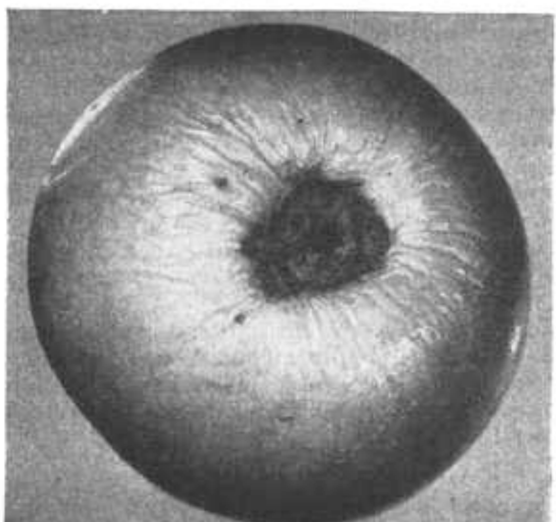
population and may make it possible to apply less spray material, thus simplifying the removal problem.

Whether a given spray treatment makes washing more difficult depends on the method of washing or the solvent employed; conversely, the solvent that can be most effectively used may be determined by the spray treatments given. The two cleaning agents that have proved most satisfactory are hydrochloric acid and sodium silicate. These are the basic materials but both may be made more effective by the addition of other materials. As mentioned previously, the use of lime or fungicides containing lime in the cover sprays leaves an alkaline residue on the fruit that makes an alkaline wash such as sodium silicate relatively ineffective. For this reason hydrochloric acid is indicated for the washing solution under eastern conditions. The use of alkaline materials such as calcium arsenate or manganese arsenate in the cover sprays also makes hydrochloric acid more effective as a washing solution. On the other hand, where lime is not used in the cover sprays washing with sodium silicate may be more effective with certain spray treatments, such as those in which fish oil or mineral oil is used.

Under eastern conditions four or five cover sprays of lead arsenate at the rate of 3 pounds to 100 gallons are usually applied to fall and winter varieties of apples. To the first or first and second sprays is usually added lime-sulfur, and to the others bordeaux mixture or lime. After such a program, the residues at harvest are normally not greatly in excess of the tolerance and usually can be readily removed by washing with a hydrochloric acid solution at room temperature.

The addition of fish oil (1 quart to 100 gallons) or mineral oil emulsion (1 gallon to 100 gallons) to the first two cover sprays does not appreciably influence the amount of residue at harvest or the difficulty of removal. It should be noted in this connection that, as mineral oil cannot be used with lime-sulfur, bordeaux must be used as the fungicide if mineral oil is used, and there is danger of burning

Figure 3.—Apple showing typical arsenical injury.



from bordeaux if cool, wet weather prevails. The addition of calcium caseinate spreader or fish oil (1 quart to 100 gallons) to the late cover sprays of lead arsenate may increase slightly the amount of residue at harvest but does not make removal more difficult with acid washing solutions under eastern conditions. The addition of mineral oil (1 gallon to 100 gallons) to the late cover sprays materially increases the amount of residue at harvest and the difficulty of removal with acid solutions. After such a program the addition of a wetting agent to the acid solution or the use of a heated solution with a wetting agent or a light mineral oil may be required for effective cleaning.

When calcium arsenate is substituted for lead arsenate in some or all of the cover sprays the residues at harvest may be somewhat lower, but the necessity for cleaning is not usually avoided, the control of the codling moth may be less effective, and the danger of spray burning to the tree and fruit may be increased.

Under eastern conditions little is known about the use of fluorine sprays and the residue problem. The indications are that, with the present methods of washing, fluorine residues are removed with greater difficulty than are lead arsenate residues.

Under northwestern conditions six to eight cover sprays are usually applied to fall and winter varieties of apples for the control of the codling moth. When lead arsenate alone, at the rate of 3 pounds to 100 gallons, is used throughout the season, the residues are sufficiently heavy to require a severe washing treatment.

The addition of fish oil (1 quart to 100 gallons) to the late sprays of lead arsenate may increase somewhat the difficulty of removal with hydrochloric acid, but it facilitates removal with sodium silicate solutions. The addition of mineral oil emulsion (1 gallon to 100 gallons) to late cover sprays greatly increases the difficulty of removal. If lead arsenate is omitted from some of the late cover sprays and mineral oil and nicotine sulfate is substituted, the amount of lead residue at harvest will be reduced, but the difficulty of its removal may be as great as when lead arsenate without the oil is used throughout the season.

Fish oil or mineral oil is commonly applied with cryolite or other fluorine sprays. When such sprays are used throughout the season the fluorine residues are sufficiently difficult to remove to require double washing with solutions heated to at least 100° F. When cryolite is applied with fish oil, the most effective cleaning is obtained with an alkali-acid combination, but when it is applied with mineral oil a dual hydrochloric acid treatment is more effective. The use of lead arsenate during the early part of the season and fluorine sprays with oil in the last two cover sprays reduces the load of lead and fluorine as compared with a complete program of either and may make cleaning easier with flood machines. Flotation washers are relatively ineffective in removing fluorine residues.

In the Middle West nicotine-bentonite sprays are sometimes used to control codling moth. Residues from such sprays are objectionable from the standpoint of appearance. They may be removed by a cold wash of sodium silicate (40 to 60 pounds per 100 gallons) plus mineral oil (1 gallon per 100 gallons).

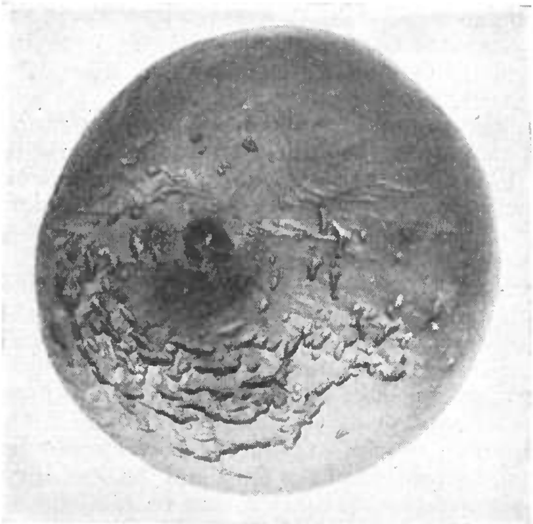


FIGURE 4.—Apple showing severe heat injury.

EFFECT OF WASHING ON KEEPING QUALITY

The washing of sound apples, when properly done, usually does not impair their keeping quality. Although certain injuries are sometimes caused by washing, these can be avoided by observing certain precautions. Injuries that may result from washing may be listed as hydrochloric acid injury, arsenic or fluorine injury, alkali injury, handling injury, heat injury, shriveling, and decay.

Hydrochloric acid injury consists of a bleaching of the skin, usually in small spots around the lenticels; frequently the bleaching is accompanied by cracking through the center of the affected area (fig. 2). Ultimately the injured area becomes depressed but remains light tan or yellowish unless arsenic was present; in that case it becomes darkened. Hydrochloric acid injury is very seldom encountered in commercial operations and usually results from prolonged exposure of the fruit to the acid, as during a shut-down of the machine or through failure of some of the fruit to progress through the machine normally. It can be prevented by keeping the apples out of the washing section when the machine is not running and by repairing the machine so as to keep the fruit moving through the solution. Rinsing that is sufficiently thorough to prevent arsenic or fluorine injury will also prevent acid injury.

During the washing process arsenic from arsenical sprays or fluorine from fluorine sprays is released in soluble forms that are toxic to the skin of the fruit, and, unless thoroughly rinsed off, they may cause injury. This injury (fig. 3) consists of a browning or blackening of the skin, usually in the calyx basin but sometimes in the steam cavity. The injury may not develop for 1 to 2 weeks after the washing. At first the injury is superficial, but in advanced stages it becomes depressed and may extend an eighth of an inch or more into the flesh. Such injury opens the way for the development of decay organisms. Ar-

senical and fluorine injuries can be avoided by changing the wash solution at intervals so that the soluble arsenic or fluorine does not become too concentrated in the wash solution and by thorough rinsing with fresh water or with limewater.

It should be mentioned that arsenical spray burning, even though it does not show up until after the washing, may have been caused by orchard conditions rather than by the washing. Wet weather during harvest and particularly with picked fruit that is standing in the orchard may start burning that does not become apparent until after the fruit is washed.

Heat injury (fig. 4) consists of a latitudinal checking or cracking of the skin, usually around the calyx but sometimes on the cheek of the apple. This injury may be apparent a few minutes after washing. The cracking of the skin results in excessive shriveling in storage and forms entry points for decay organisms. Heat injury can be prevented by careful control of the temperature and time of exposure. The temperature and time of exposure that can safely be used depend on the variety and condition of the fruit and the washing solution used. In general, a temperature of 100° F. can be used for exposures of 1 minute or less without injury. With tender-skinned varieties such as McIntosh and Esopus Spitzenburg and to a less extent with York Imperial and Jonathan, lower temperature or shorter exposures should be used than with tougher skinned varieties such as Winesap. Fruit that is turgid, as it is likely to be immediately after picking, particularly after wet or cloudy weather, is more susceptible to heat injury than fruit that is slightly shriveled as after a period in storage. Higher temperatures can generally be used with sodium silicate solutions and acid solutions to which mineral oil has been added than with solutions of acid alone. Temperatures of 110° to 120° for 20 to 35 seconds' exposure are frequently used with sodium silicate solutions, particularly when washing apples that have been in storage. When wetting agents are used with hydrochloric acid, somewhat lower temperatures should be employed than when acid alone is used.

Temperatures should not be maintained any higher than necessary to obtain effective cleaning as the hazard of injury to the fruit is greatly increased by high temperatures. Increased susceptibility to shriveling and to the entrance of decay-producing organisms may result from the use of high temperatures even though injuries to the skin are not visible. The common belief that the storage life of apples is drastically shortened through so-called cooking in heated washing solutions is based upon experiences of having apples shrivel severely or decay rapidly, when injured by the washing process. Although slight influences on the rate of ripening may result from severe washing treatments, these are not measurable in the commercial storage life of the fruit.

The skin of the apple is its chief protection against the entrance of decay-producing organisms. If the fruit is handled roughly so that the skin is punctured or broken and is washed with an old solution that has become heavily contaminated with spores, a large percentage of the fruit may develop decay during storage. Severe washing treatments may cause microscopic injuries in the skin or in the calyx tube of a fruit sufficient for invasion by decay-producing organisms. Although the washing process may, in this way, make apples more susceptible to decay, the mechanical action of washing removes thou-

sands of spores from the fruit as it comes from the orchard. For this reason decay in apples may be reduced as a result of washing, provided the washing solutions are changed daily, careful attention is given to solution temperatures and concentrations, the fruit is rinsed with copious amounts of clean water, and careful handling is practiced.

The heating of washing solutions to 100° F. or higher results in the killing of spores of rot-producing organisms within a few hours. Heated solutions therefore carry fewer live spores than cold solutions. Where solutions are used below 100° it is advisable to heat them to 130° or higher on nights when the solutions are not changed, in order that the spore population may be largely killed before the next day's operation. A heated solution of sodium silicate is more effective in killing spores of some rot-producing organisms than is one of hydrochloric acid. Apples are also slightly less susceptible to decay when washed with sodium silicate than when washed with hydrochloric acid solutions.

WASHING PEARS

In general, the methods and directions for washing apples are applicable to pears and other fruits also. However, some fruits require special treatment in certain respects, and therefore some special consideration will be necessary.

Pears do not generally require as heavy spray applications as apples and are therefore more easily cleaned. Hydrochloric acid solutions are generally indicated for washing pears. Sodium silicate solutions should not be used for washing russet varieties of pears, such as Bosc and Winter Nelis, as such solutions cause a distinct darkening of the russet areas, but they may be used for pears that are not russeted.

Flotation washers are not well suited for washing pears as most varieties will not float in the acid solutions or in water.

Some varieties of pears, such as Anjou and Comice, have very tender skins and must be handled with extreme care in order to prevent skin breaks. The use of dry-cleaning equipment such as brushers or wipers is especially hazardous with such varieties and may produce skin scratches and abrasions.

Pears usually can be effectively cleaned with acid solutions at room temperatures. Kerosene or other mineral oils should never be added. When heated solutions are necessary temperatures as high as those suggested for apples may be used safely.

CLEANING PEACHES

Peaches are usually sprayed with lead arsenate to control the plum curculio. Such sprays are applied while the fruit is still very small, and no excessive residues are likely to remain on the fruit at harvest. Dry-wiping machines are frequently used to remove the fuzz or pubescence from peaches, and such treatment also removes considerable spray residue from fruit that has been sprayed late in the season.

Peaches cannot be washed with hydrochloric acid solutions, as severe acid injury is sure to follow such treatment.

WASHING CHERRIES [1]

Cherries are frequently sprayed with lead arsenate for the control of the cherry fruitfly. Such sprays are usually applied early in the season, and residues in excess of the tolerances are not generally encountered. Lead arsenate residues have been removed from cherries by washing with dilute hydrochloric acid solutions and rinsing with fresh water. There was no increase in decay after such treatment nor was there any splitting of the fruit, provided the washing did not take place until several hours after picking. The use of acetic acid with a wetting agent instead of hydrochloric acid has been reported as effective in removing residue from cherries, with less danger from cracking.

Cherries can be washed in dipping tanks by placing the fruit in small slàtted crates with about a quarter of an inch space between the salts. Cherries might also be washed in some types of commercial washers in which are used conveyors such as the walk-along type that would carry flat-slatted crates through the machines. Washing in water as practiced in most canneries removes considerable amounts of spray residue and may be sufficient for either sweet or sour canning cherries that have residues only slightly in excess of the tolerances.

WASHING GRAPES [2]

Control of the grape-berry moth in certain sections of the United States is accomplished by spraying with lead arsenate, and spray residues at harvest in excess of the tolerances may result. Grapes have been found to carry residues considerably in excess of the tolerances when given only two applications of lead arsenate, the last application being applied shortly after blossoming. Spray residues have been effectively removed from American varieties of grapes by washing in dilute solutions (0.5 to 1.0 percent) of hydrochloric acid at room temperature and rinsing with fresh water. The washing can be accomplished in dipping tanks or in commercial machines with suitable conveyors by means of slatted crates, as suggested for cherries.

Because of the bunched condition of the fruit it cannot be effectively and quickly dried. If the wet grapes are packed in large containers, such as bushel or half-bushel baskets, drying will be very slow, and excessive mold and decay are likely to result, particularly if there are many cracked berries. For the fresh-fruit trade, therefore, grapes that are to be washed must be handled with great care and should be packed in baskets of 12-quart size or less. Holding the grapes at low temperatures (32° to 40° F.) will greatly reduce mold development.

WASHING CURRANTS

Currants are sometimes sprayed with lead arsenate to control the currant worm. Because of the very small size of the berries and the large proportion of stems, one application of lead arsenate more than a month before picking is likely to result in residues in excess of the tolerances. Such residues can be effectively removed by washing with

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[1] See ROBINSON, R. H. ARSENICAL SPRAY RESIDUE ON CHERRIES. Oreg. Agr. Expt. Sta. Bul. 298, 15 pp., illus. 1932.

[2] LUTZ, J. M., and RUNNER, G. A. STUDIES ON THE REMOVAL OF SPRAY RESIDUE FROM GRAPES. Amer. Soc. Hort. Sci. Proc. 29: 345–349. 1932.

solutions of hydrochloric acid (0.5 to 1.5 percent) at room temperature and rinsing with fresh water.

Currants intended for the fresh-fruit markets are usually shipped in crates. To avoid extra handling the currants should be washed in the quart boxes in which they are to be shipped, by placing the boxes in flat-slatted crates and dipping them in the acid solution and rinse water, or by means of commercial fruit washers with suitable conveyors, as suggested for grapes and cherries. If they are washed in a flood machine the currants must be covered with cheesecloth to keep them from being splashed out of the boxes.

It is not feasible to dry the currants effectively and quickly after washing. The moisture in the boxes is favorable to the development of mold, particularly if there are many cracked or mashed berries and if they are held at high temperature. However, washing need not materially increase decay and mold provided the berries are sound, are very carefully handled, and are shipped under refrigeration or under conditions that permit rapid drying.

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